ORIGINAL PAPER

EFFECT OF LONG-TERM FERTILIZATION ON THE AVAILABLE TOXIC ELEMENT CONTENT OF DIFFERENT SOILS

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ABSTRACT

The National Long-Term Fertilization Trials were set up more than 30 years ago and in that time soil and water protection and environmental relations of fertilization had not been the direct aim of research. From the agricultural load the use of phosphate fertilizers gets outstanding attention because of the accumulation of toxic heavy metals. The aim of our research was to study the influence of long-term, intensive fertilization on the available toxic element content and accumulation in different soils. Samples were collected from 8 experimental sites with equal treatments from the depth of 0-20 cm.

The so-called available, 0,1M KCl + 0,05M EDTA extractable element content was determined. In the paper the results of Cd, Pb, Cr, are discussed in details. The experimental results of toxic elements show that the 28-year old constant fertilization treatments did not result higher values than the accepted concentration level, even they did not approach it.

KEYWORDS: long-term trials, fertilization, available, toxic elements, soil

DETALIED ABSTRACT

The National Long-Term Fertilization Trials were set up more than 30 years ago and in that time soil and water protection and environmental relations of fertilization had not been the direct aim of research. Since then more and more demand have arisen from environmental point to get knowledge of macro, micro and toxic element content of soils. The acidification of soils increases the solubility of metal elements, which through unwanted concentration levels may result toxicity. Acid soils are therefore more sensitive to contamination and this kind of agricultural load. The effect of toxic concentration appears through the ion uptake of plants, though it may influence the biological and physical-chemical properties of soils. The trace element content of soils may be different due to their origin and geology, however anthropogenic effects like fertilization may have further influence.

The agricultural load has the widest extent and affects the whole biosphere. Fertilization changes the nutrient status, pH, etc. of soils. Some heavy metals may accumulate in the soil or the solubility change. From the agricultural load the use of phosphate fertilizers gets outstanding attention because of the accumulation of toxic heavy metals. The aim of our research was to study the influence of long-term, intensive fertilization on the available toxic element content and accumulation in different soils. Samples were collected from 8 experimental sites with equal treatments from the depth of 0-20 cm.

The so-called available, 0,1M KCl + 0,05M EDTA extractable element content was determined. In the paper the results of Cd, Pb, Cr, are discussed in details. The experimental results of toxic elements show that the 28-year old constant fertilization treatments did not result higher values than the accepted concentration level, even they did not approach it.

INTRODUCTION

Soil fertility decreases due to extreme physical, chemical and biological conditions, e.g. lack or surplus of nutrients, water, organic or mineral colloids, low or high pH, accumulation of toxic (metal) elements, anaerobe conditions, salt accumulation, narrow A horizon, environmental load, etc.

There are many possible ways for heavy metals to get into the soil and to the soil-plant system and all through this the food chain. It can happen by air-pollution; by natural ways such as volcanic actions, or dust storms; through agricultural activity using artificial fertilisers, manure, or pesticides. They can derive also from sewage sludge, smog, or the precipitation of dry and wet sediments of the atmosphere [7]. 95% of Pb in the atmosphere has anthropogenic origin, 60% of Pb load comes from the traffic. Plant examinations by roads showed 20-30 and 50-100 mg kg^{-1} Pb in plant tissues [3].

There is an exceptionally dangerous heavy metal, the cadmium. According to literature it has a toxic effect on plants animals, and human as well [1].

Plant species and varieties (cultivars) differ widely in their ability to absorb, accumulate and tolerate heavy metals [3], [8-11]. There are plants, which can accumulate, in great quantities Cd without toxicity symptoms [9, 12]. Contrary to Pb it enters plant tissues very quickly and may accumulate in the green parts [13].

Cr in the soil is also phytotoxic, however it is a poison for animals and human beings [6]. Cr contamination induces modifications in the uptake of elements and disturbs metabolism [8]. It can be found in different forms in the soil. Chromate and dichromate similarly to nitrate may reach the soil water. Cr can be found in soils generally between 5-100 mg kg^{-1}, in some cases 500-1000 mg kg^{-1} mostly in unavailable form, binding strongly to colloids. There are only limited amounts in plant shoots; hence it accumulates in 98% in the root system. Its concentration in the shoots is 0,02-1 mg kg^{-1} [3].

The importance of long-term experiments has increased significantly proportional to their age. The accumulated effect of external environmental load from atmospheric sediments and fertilizers on the biomass production, quality of crops, soil fertility, utilization and losses of nutrients can be measured in these trials and compared to earlier periods.

Agriculture and environment protection can get reliable answers connected to the cycles of elements and in relation to the environmental load of soil water. The long-term fertilization experiments provide great possibility to study the process of soil contamination.

In the paper experimental results on the change of Pb, Cd and Cr concentrations of soils in eight sites from the Network of the National Fertilisation Long-term Trial [5] are presented. The effect of long-term fertilisation (28 years) on these element concentrations is presented in relation to some important fertilizer treatments (NPK doses).

MATERIALS AND METHODS

The National Long-Term Fertilization Trial Network was set up in 1968, in eight different agro-ecological regions. Table 1 shows the types and important physical and chemical properties of all the soils in the experiments. NPK fertilizer levels are as follows: N= 0 – 50 – 100 – 150 – 200 – 250 kg ha^{-1} $year^{-1}$, P (P_2O_5) = 0 – 50 –

100 – 150 – 200 kg ha^{-1} $year^{-1}$ and K (K_2O) = 0 – 100 – 200 kg ha^{-1} $year^{-1}$. These treatments cannot be found in all combinations. Total application after 28 years: 2800-4200-5600-7000 kg N ha^{-1}, 1400-2800-4200-5600 kg P_2O_5 ha^{-1}, 2800-2800-2800-5600 kg K_2O ha^{-1}. Cropping pattern is a winter wheat-maize double cropping system in a four-year rotation. There has been 4-8-12-16-20-24-28- year with seven rotation cycles. For the study treatments as follows have been selected:

Fertilization (NPK) treatments

1/ unfertilized control
(coded: 000)

2/ 100 kg N ha^{-1}, 50 kg P_2O_5 ha^{-1}, 100 kg K_2O ha^{-1} (coded: 211)

3/ 150 kg N ha^{-1}, 100 kg P_2O_5 ha^{-1}, 100 kg K_2O ha^{-1} (coded: 321)

4/ 200 kg N ha^{-1}, 150 kg P_2O_5 ha^{-1}, 100 kg K_2O ha^{-1} (coded: 431)

5/ 250 kg N ha^{-1}, 200 kg P_2O_5 ha^{-1}, 200 kg K_2O ha^{-1} (coded: 542)

Samples were collected from 8 experimental sites with equal treatments from the depth of 0-20 cm. The so-called available, 0,1M KCl + 0,05M EDTA extractable Pb, Cd and Cr content was determined [2]. These elements have been determined from samples collected in the 28th year of the trial.

Mathematical statistical analysis of the experimental data was done by ANOVA using of SPSS for Windows statistical program.

RESULTS

The available Pb content of the experimental soils has mainly shown site dependence in the eight places (Table 2). The difference between soils in available Pb content is 4-5 fold. Pb load originated in the greatest content from traffic, thus the highest value(s) came from Keszthely due to the close main road.

The 200-250 kg N ha^{-1} $year^{-1}$ and the 150 – 500 kg P_2O_5 ha $year^{-1}$ treatments have slightly increased the Pb content of acid soils (Kompolt, Putnok, Keszthely) contrary to calcareous soils (Nagyhörcsök, Iregszemcse), as it can be found in literature, $CaCO_3$ decreases the availability of Pb. Experimental results even do not approach the accepted concentration level of Pb.

The available Cd content of the experimental soils varied between 0,06 – 0,16 mg kg^{-1}. The highest values were measured at Hajdúböszörmény and Karcag sites, while the lowest values came from Putnok, Iregszemcse and Nagyhörcsök. Statistically significant treatment effect in the upper 20 cm soil layer could not be found in none of

Table 1: Soil Properties of the Eight Sites of the Long-Term Field Experiment Network "OMTK"

	Experimental Sites							
Properties	NH[a]	IR	BI	KO	KA	PU	KE	HB
Soil type (FAO)	Calcaric Phaeosem	Calcaric Phaeosem	Luvic Phaeosem	Haplic Phaeosem	Luvic Phaeosem	Ochric Luvisol	Eutric Cambisol	Luvic Phaeosem
Soil type (USDA)	Mollisol	Mollisol	Mollisol	Mollisol	Mollisol	Alfisol	Alfisol	Vertisol
Soil texture	Loam	Loam	Loam	Clay loam	Clay loam	Clay loam	Sandy loam	Clay
Soil OM, %	2.7	2.4	1.9	2.6	2.7	2.0	1.7	3.5
Soil pH_{KCl}	7.2	7.4	5.6	3.9	4.7	3.9	5.9	6.1
$CaCO_3$, %	5.0	8.0	-	-	-	-	0.1	Traces
Clay % (<0.002 mm)	23	22	33	41	37	28	24	35

[a]Experimental sites: NH: Nagyhörcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény

Table 2: The heavy metal concentration in experimental soils

NPK treatments	NH[a]	IR	BI	KO	KA	PU	KE	HB
	Experimental Sites							
	Pb							
000	2,21	2,39	5,95	6,19	6,25	5,83	8,29	7,32
211	2,08	2,25	5,72	4,76	6,25	5,95	8,96	7,64
321	2,49	2,66	6,04	4,86	6,76	5,57	8,05	7,85
431	3,03	2,53	6,11	6,1	6,84	6,85	10,35	7,62
542	2,57	2,67	6,45	6,22	6,85	6,59	9,75	7,48
$LSD_{5\%}$	0,73	0,59	0,84	0,65	0,48	1,19	4,88	3,53
	Cd							
000	0,09	0,1	0,13	0,13	0,14	0,08	0,12	0,14
211	0,09	0,09	0,13	0,11	0,14	0,08	0,11	0,14
321	0,09	0,10	0,13	0,12	0,16	0,07	0,11	0,16
431	0,11	0,10	0,15	0,12	0,15	0,09	0,12	0,14
542	0,08	0,11	0,14	0,13	0,15	0,08	0,13	0,15
$LSD_{5\%}$	0,02	0,02	0,02	0,02	0,02	0,01	0,03	0,07
	Cr							
000	0,05	0,06	0,15	0,13	0,25	0,11	0,12	0,06
211	0,18	0,17	0,34	0,22	0,25	0,23	0,23	0,16
321	0,18	0,19	0,30	0,22	0,26	0,23	0,25	0,17
431	0,09	0,04	0,18	0,12	0,27	0,11	0,13	0,06
542	0,07	0,06	0,17	0,12	0,28	0,11	0,13	0,06
$LSD_{5\%}$	0,04	0,02	0,06	0,02	0,03	0,02	0,027	0,02

[a]Experimental sites: NH: Nagyhörcsök; IR: Iregszemcse; BI: Bicsérd; KO: Kompolt; KA: Karcag; PU: Putnok; KE: Keszthely; HB: Hajdúböszörmény

soils. The increasing amounts of P fertilizers applied for 28 years have not influenced significantly the available Cd content of soils. The Cd content of P fertilisers is influenced by the raw material and the method of preparation as well. In Hungary, because of the very low Cd content of fertilizers (1 mg kg^{-1}) even under the intensive fertiliser application of the seventies and eighties, less than 0,3-0,5 g ha^{-1} $year^{-1}$ Cd contaminated the soil [8, 4].

Unfortunately, the original heavy metal content of the experimental soils, from 1968 is unknown, since the environmental load was not in focus in that time. The results of Cd measurements show that Cd concentration even does not approach the accepted level in the experiment soils.

The third element of this study is the Cr. The available Cr content shows significant differences due to the soils and nutrient supply as well (0,05 – 0,28 mg kg^{-1} soil). There was no treatment effect except the Karcag site. In seven experimental sites significantly higher Cr content was found in plots where lower fertilizer doses had been applied. Our results can strengthen the opinion from literature that phosphorus content of soils may great importance on the availability of Cr. In our experiment lower available Cr content was measured from soils where higher P_2O_5 fertilizer treatments occurred.

It can be stated that in the 28-year long-term fertilization trial the effect of treatments in case of Cr content of soil could be detected in the greatest extent.

DISCUSSION

Primarily the site conditions of the eight experimental soils have influenced the available Pb content. The increasing doses of NPK fertilizer treatments applied equally for 28 years have not resulted statistically significant differences in the 0-20 cm depth of the experimental soils.

The available Cd content of the experimental soils varied between 0,06 – 0,16 mg kg^{-1} The increasing amounts of P fertilizers applied for 28 years have not influenced significantly the available Cd content of soils.

The extremely toxic Cd content did not increase due to the P fertilization treatments. There are geo-chemical differences between the Cd content of experimental soils. In our experiment lower available Cr content was measured from soils where higher P_2O_5 fertilizer treatments occurred. The effect of long-term fertilization in case of Cr content of soil could be detected in the greatest extent.

The long-term fertilization experiments are the most reliable means to follow the process of soil pollution, accumulation of heavy metals in soils as a function of fertilization. The experimental results of toxic elements show that the 28-year old constant fertilization treatments did not result higher values than the accepted concentration level, even they did not approach it.

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